Inheritance of Ability

UNIVERSITY OF LONDON
FRANCIS GALTON LABORATORY FOR NATIONAL EUGENICS

EUGENICS LABORATORY MEMOIRS. I.

THE INHERITANCE OF ABILITY,

BEING A STATISTICAL STUDY OF THE OXFORD CLASS LISTS AND OF THE SCHOOL LISTS OF HARROW AND CHARTERHOUSE.

BY
EDGAR SCHUSTER, M.A.,
FELLOW OF NEW COLLEGE, OXFORD.
FIRST FRANCIS GALTON RESEARCH FELLOW IN NATIONAL EUGENICS
IN THE UNIVERSITY OF LONDON
AND
ETHEL M. ELDERTON,
FRANCIS GALTON SCHOLAR IN NATIONAL EUGENICS IN THE UNIVERSITY OF LONDON

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THE FRANCIS GALTON EUGENIC LABORATORY.

University of London, University College, Gower Street, W.C.

[The temporary address of the Laboratory is 88, Gower Street, W.C.]

The Laboratory is under the supervision of Professor Karl Pearson, F.R.S., in consultation with Mr Francis Galton, F.R.S.

Francis Galton Fellow in National Eugenics: David Heron, M.A.

Francis Galton Scholar: Miss E. M. Elderton.

Computer: Miss Amy Barrington.

Advisory Committee.—The following have kindly consented to aid the Staff of the Laboratory in special forms of enquiry:—

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Some reconstruction of the Francis Galton Laboratory having taken place, it seemed desirable to provide the workers associated with it with a direct channel of publication of their own, in which their more extended memoirs should appear. It is hoped that the present series may be issued at short intervals. Subscribers should notify their intention of taking in the memoirs as they are published to Messrs Dulau & Co. Requests to exchange with similar publications, with archives and journals dealing with demographic and sociological problems, or with census reports should be directed to The Editor, Eugenics Laboratory, University College, Gower Street, London, W.C.

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In the Appendix Professor Pearson deals with an important factor tending to modify our results, the consideration of which is omitted from the body of the Memoir. With the views which he expresses we are entirely in agreement.

INTRODUCTION.

At the time of the first publication of Mr Galton's *Hereditary Genius*, in 1869, the belief in the hereditary nature of inborn natural ability was held by very few; but so great has been the influence of that and other works that at the present time it would be almost impossible to find an educated person to dispute it, and the inheritance of psychical characters ranks with motor-cars and the morphia habit among the ingredients in the composition of the contemporary novel.

With the diffusion of an idea it becomes progressively more vague and indefinite, so that an attempt to give it crispness of outline becomes all the more desirable, and for this purpose one must substitute, for a description that is merely qualitative, one that is also quantitative, and, having recognized the pressure and direction of a force, one must endeavour to measure it.

Such a description of the inheritance of the mental and moral qualities has been given by Professor Pearson in his Huxley Lecture before the Anthropological Institute, and it has been our endeavour to confirm and supplement his results with others obtained from different material treated at the outset in a fundamentally different way.

The essential difference between his results and ours is that the former are based on the estimates of the school teachers of the ability of pairs of brothers, or sisters, or brothers and sisters, while we have used the results of the examinations for the B.A. degree at Oxford, the position in the school of boys in the school at definite times in their life or in their school career. This has enabled us with regard to the Oxford material to measure the average resemblance between father and son, as well as that between brother and brother, and we shall endeavour to show that, after certain allowances have been made, our results are substantially in agreement, not only with those of Professor Pearson, which are referred to above, but also with other work on more easily measurable characters.

Perhaps it would be as well to define, as exactly and as simply as we can, the meaning we attach to the phrase "measure the average resemblance between father and son." We know that the intelligence of the fathers varies very much and so also does that of the sons; we know in a general sort of way that the sons of those fathers who are above the average of fathers, are themselves on the whole more intelligent than the average of sons; if we take a group of fathers,

each of whose intelligence is the same definite amount, which we will call A*, above the average, their sons will form a group which varies considerably, but whose average intelligence is a certain definite amount, which we will call B*, above that of all the sons of all the fathers.

We presume, and there is considerable reason for the presumption, that whatever be the magnitude of A the relation of B to A, that is to say the value of the fraction B is, within certain limits, the same, and we want to find out exactly what it is. When we have found it we shall have measured the average resemblance between father and son, for if the resemblance be complete and perfect then the value of this fraction would be 1, for B would be equal to A, that is to say that the sons of any particular group of fathers of given intelligence will differ from the average of all the sons by exactly the same amount as the intelligence of their fathers differed from the average intelligence of all the fathers. If there be no resemblance the value of the fraction is 0, and every intermediate value between 1 and 0 expresses a different degree of resemblance.

A statistical statement of the effect of inheritance on the mass such as is attempted here is quite independent of what view is taken of the truth of Mendel's laws and whether they be universal in their application or not; this fact has been frequently insisted upon, yet it seems desirable to do so once again. Even if we believe in the universal applicability of these laws—and it cannot be claimed that this has as yet been proved—they would tell us nothing concerning the inheritance of inborn ability until such a time as some general law of dominance has been discovered and some better definition of a unit character evolved than that which is at present accepted—namely a character that is inherited according to these laws. Furthermore, granting that this time had come, Mendel still would tell one nothing unless in each case both parents were known, and through a necessary limitation of the material this condition does not obtain. Enough has been said to show to any but the extremists of the Mendelian school that this work, if properly executed, is of value, and that if this is not the case the blame must be attached to the authors personally, and not to the methods which they employ nor to the school to which they belong.

* For the sake of simplicity we have omitted to state in the text that A is measured in terms of the standard deviation of fathers, and B in terms of the standard deviation of the sons.

PART I.

THE EVIDENCE OF THE OXFORD CLASS LISTS.

A. *Sources of Material.*

THE standard biographical works concerning past and present members of Oxford University are Foster's *Alumni Oxonienses* and its continuation *Oxford Men and their Colleges*. The former is divided into two parts, each consisting of four octavo volumes—an earlier one covering the years 1500—1714, and a later one, which deals with those who entered the University between 1715 and 1886, while the continuation brings the information up to 1892. Since the Oxford honours examinations on which our tables are largely based were only instituted in 1800, only a portion of the later part could be employed, but it will be seen that in spite of this an ample amount of material has been obtained.

The biographical notice of each member of the University gives, among other information, the name of his father and the name of the college to which he belonged; it tells whether or no he took the B.A. degree, and if so at what date. Thus from this we were enabled to find the relationship between a large number of pairs of fathers and sons, and of a large number of families of brothers, while the remaining information which we required, namely the class obtained in the case of an honours degree, was supplied by the *Oxford Historical Register*. The last-named work contains among other useful features an alphabetical register of all those who obtained honours or distinctions at the University between 1220 and 1900; after each name is given the college to which he belonged, which is useful for purposes of identification, and a dated list of the honours and distinctions obtained. Thus the labour of finding out which class, if any, was obtained by each of the several thousand persons included in our tables was reduced to a minimum. The history of the honours examinations at Oxford, which may be found summarized on p. 191 of the *Historical Register*, stated still more briefly, is as follows: From 1800—1806 the honours examination was conducted separately to the pass examination, the candidates were examined both in classics and mathematics, and there were two classes of honours, but during those years, either very few people entered for honours, or the standard was exceedingly high, for only 14 men appear in either the first or second class. From 1807—1830 alternative subjects were introduced, namely *Literae Humaniores* or classics, and *Disciplinae Mathematicae et Physicae* or mathematics; all candidates, whether

for honours or no, were examined together, and there were in 1807—8 two classes of honours, which were increased to three in 1809. In 1830 an extra class was added and those who were not candidates for honours were examined separately from those who were, but permission was given to the examiners to include in the fourth class honours list those candidates for the pass degree whom they thought worthy of it. This enactment came to an end in 1865, when the honours examination and pass examination were allotted to different bodies of examiners. From 1830 onwards the four classes of honours have remained the same, although the number of subjects in which the examination is held has been greatly increased.

Up to the year 1834 the members of New College were exempt from the University examinations, a privilege which shut out that college from the "rapid improvement in industry and intellectual vitality which that measure brought with it for the best of Oxford colleges." At that date it was voluntarily renounced by the college, but up to then New College men can hardly be considered to have been members of the University as far as examinations are concerned and are therefore not included in the tables which we have made.

B. *The Resemblance between Father and Son.*

The first step in the process of tabulation was to divide the men into three classes according to the date at which they took, or should have taken their degrees, the limits of the three groups being as follows: 1800—30, 1830—60, 1860—92. We will consider the latest of these first, namely the group 1860—92, and deal only with those men whose fathers were educated at Oxford. They were found to consist of 2459 persons, of whom 149 had been placed in the first class, 329 in the second, 377 in the third, 190 in the fourth; of whom 868 had taken merely a pass degree, and 546 had failed for one reason or another to take any degree at all. Each of these six classes was sorted again according to the degree taken by the father; of the 149 first class men, 27 had fathers in the first class, 27 in the second class, 14 in the third class, 13 in the fourth, and 53 with pass degrees and 15 without degrees; of the 329 second class men, 52 had fathers in the first class, 54 in the second class, 33 in the third class, 30 in the fourth class, 138 with pass degrees, and 22 with no degrees; of the 377 third class men, 47 had fathers in the first class, 64 in the second, 47 in the third, 42 in the fourth, 157 with pass degrees, and 20 with no degrees; of the 190 fourth class men, 20 had fathers in the first class, 27 in the second class, 22 in the third class, 17 in the fourth, 91 with pass degrees, and 13 without degrees; of the 868 men who took pass degrees, 41 had fathers in the first class, 79 in the second, 95 in the third, 87 in the fourth, 479 with pass degrees, and 87 with

no degrees; of the 546 who took no degrees, 31 had fathers in the first class, 39 in the second class, 46 in the third class, 52 in the fourth, 277 with pass degrees, and 101 with no degrees. These results will be found stated in a less distressing way in Table I A., but at the risk of seeming, or possibly it might be more accurate to say, in spite of the certainty of being insufferably tedious, we have repeated them in words here, so that those people who are quite unfamiliar with this class of table should have no difficulty of apprehending its meaning.

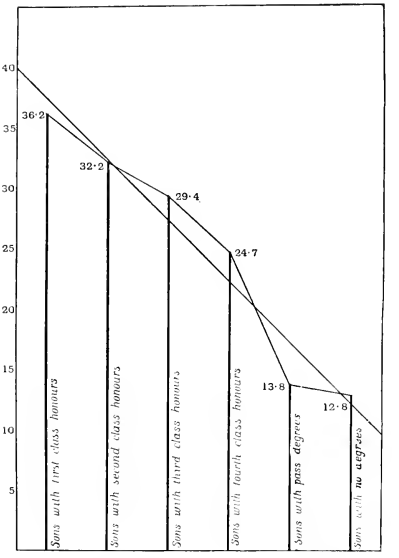

DIAGRAM I. (date of degree of sons, 1860—92).

The heights of the vertical lines show in what percentage of cases the fathers have taken either first class or second class honours. The diagram is intended to show that the percentage of fathers who obtained this degree of distinction diminishes with some regularity, as one passes downwards from the sons with first class honours to those with no degrees.

Even without any mathematical treatment we can learn a great deal concerning heredity from it. Thus it will be seen from Table I B. that of the fathers of the first class men 36·2 per cent. obtained either a first or a second class themselves, and thus were on the whole slightly superior to those of the second class men of whom only 32·2 per cent. reached this standard; a stage lower is reached in the fathers of the third class men, among whom the percentage of first and second

class men has sunk to 29·4, and the percentage becomes progressively lower as we go to the lower classes; thus it is 24·7 among the fathers of the fourth class men, 13·8 among those of the pass men and 12·8 in those of the no degree class.

The two points to be noticed about these figures are firstly that the percentage of first and second class fathers diminishes as one passes down through the various classes of sons, and secondly that it does so in a very orderly way. In order to show both these points quite clearly Diagram I. has been constructed. In this diagram the height of the six vertical lines is proportional to the percentage of fathers in the first or second class of each of the six groups of sons respectively. The upper end of the left hand upright, which represents this percentage among the fathers of first class sons, and the upper ends of the five other uprights, which indicate the same fact concerning the fathers of the five other classes of sons, lie almost on a straight line, shown in the diagram, which slopes down steeply from left to right, making an angle of 45 degrees approximately with the horizontal.

One more fact must be referred to concerning Table I A. before leaving it for a time to consider Table II A. It may give the impression that exactly the same number of fathers are included in it as sons; that is to say that it deals with only one son of each 2459 fathers; but this is not the case. 2459 men of the younger generation are included, but as in some cases two or three or even more of these are sons of the same father he may be included two or three or even more times, being counted once over for each of his sons that are dealt with in the table.

We will now pass on to the consideration of Table II A., which has been constructed in exactly the same way as Table I A., but out of entirely independent material, for in this case all the sons took their degrees or should have taken them prior to 1860, but since no fathers prior to 1800 could be included it happens that almost all the sons took their degrees between 1830—1860, and all the fathers between 1800—1830.

As will be remembered the fourth class of honours was not introduced till 1830, so that those fathers who took honours are only divided into three classes. If we examine this table in the same way as we have examined the previous one we shall find a remarkable agreement, for 41·9 per cent. of the sons in the first class had fathers in either the first or second class, and the percentages of the remainder whose fathers achieved this distinction are as follows: 40·7 per cent. of the second class, 33·3 per cent. of the third, 28·1 per cent. of the fourth, 20·1 per cent. of the pass degree men, and 12·9 per cent. of those who took no degree. These numbers are shown graphically in Diagram II. As in Diagram I. the upper ends of the vertical lines which represent the percentages lie almost on a straight line which slopes steeply downwards from left to right.

Enough has now been said to show not only that signs of hereditary influences are well marked, but—although nothing certain can be predicted in individual cases—there is a considerable regularity when we deal with large numbers, a regularity which becomes more marked as the numbers are increased. However we proposed to go further than this and make a definite measure of the intensity of this force, and we will now go on to describe the results of this attempt.

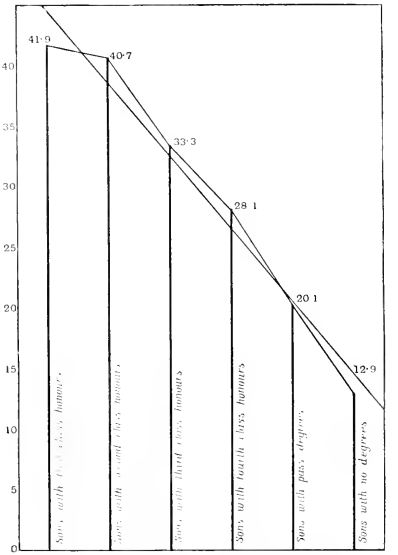

DIAGRAM II. (date of degree of sons, 1830—60).

The heights of the vertical lines show in what percentage of cases the fathers have taken either first class or second class honours. The diagram is intended to show that the percentage of fathers who obtained this degree of distinction diminishes with some regularity, as one passes downwards from the sons with first class honours to those with no degree.

Two methods have been used in doing this, namely that of "Contingency" and that of "Fourfold Correlation." The former of these will be found in the paper by Professor Karl Pearson "On the Theory of Contingency and its relation to Association and Normal Correlation," which forms No. 1 of the Biometric Series of the *Drapers' Company Research Memoirs*, published by Dulau and Co. in 1904. The latter will be found fully described in the paper by the same author "On the Correlation of Characters not quantitatively measurable" (*Phil. Trans.*

Vol. cxcv. A. pp. 1—47). It will be interesting to see how far the results obtained by the two methods used are in accordance with one another. With regard to the first named or "Contingency" method two slightly different variations of it are employed, the result of one of these, called "the Mean Square Contingency Coefficient," and represented by the symbol C_1, was found for Table I A. to be ·26, while for Table II A. it was ·29. The result of the other, called "the Mean Contingency Coefficient," and represented by the symbol C_2, gave ·29 for Table I A. and ·31 for Table II A.

In order to obtain the correlation coefficients by the fourfold method from Tables I A. and II A. it is necessary to reduce these tables to their simplest form. As this simplification can be done in many slightly different ways, slightly different values of the correlation coefficient may be found. Thus Tables I B., I C., and I D. are simplifications of Table I A. Table I B. tells one that of the 2459 sons, 478 obtained honours in classes I. and II.; whereas 1981 were placed in the third or fourth classes or obtained either a pass degree or no degree; and that of the 478, 160 had fathers of equal distinction to themselves and 318 who were inferior to them, having merely obtained third or fourth classes or pass degrees, or having obtained no degree at all; of the 1981 composing the inferior class of sons, 348 had fathers in the upper class and 1633 in the lower.

From this table the correlation coefficient, for which the symbol Υ is used, was calculated and found to be ·29. Table I C. was made in exactly the same way as I B. except that the division between the sheep and the goats was made below the third class instead of below the second, so the former category is larger than in the previous case, both with regard to the fathers and to the sons; it is unnecessary to repeat the numbers here, as they are set out in the table in question. The correlation coefficient calculated from this table = ·31. In making Table I D. the same process was repeated except that all those who obtained honours were separated from all those who did not do so. The value of the correlation coefficient obtained was ·28. Thus it will be seen that the value of this coefficient is in this case very much the same whether the division between the upper and lower groups of fathers and between the upper and lower groups of sons, is made beneath the second class, the third class, or the fourth class. The mean of the three values obtained is ·293.

Tables II B. and II C. correspond with Tables I B. and I C. and are made from the earlier material classified in Table II A. in precisely the same way as these tables are made from the more modern material included in Table I A. The correlation coefficients obtained from them are ·34 and ·33 respectively, the mean of which is ·335, a somewhat higher value than the ·293 mentioned above.

Table III. summarizes all the coefficients calculated hitherto; it shows the degree of similarity in the results which may be expected in treating two quite independent sets of material each by three different methods. Thus if we consider

unity to be the measure of perfect resemblance and nothing of no resemblance, by disregarding minor differences and speaking somewhat broadly, we may say that degree of intellectual similarity between father and son, as indicated by the degrees which each took, is ·3 or nearly $\frac{1}{3}$.

C. *Resemblance between Brother and Brother.*

We will now pass on to the consideration of fraternal resemblance. In Table IV A. the material used consisted of those families of brothers in which the majority of the brothers took their degrees between the years 1860—1892; it is constructed much on the same principle as Tables I A. and II A., except that instead of considering each son in relation to his father, every man included is considered in relation to each of his brothers taken in turn. Thus in dealing with a family of two brothers, *X* and *Y*, who may have taken a first and a fourth class respectively, in the first place *X* is taken and is entered in the fourth square from the left of the top row as being a first class man with a fourth class brother, and then *Y* is entered in the left hand square of the fourth row as being a fourth class man with a first class brother, so that each family of two contributed two to the total number of 4266 pairs. Now let us consider a family of three brothers, *X*, *Y* and *Z*, who were placed respectively in the first, second and third classes; *X* is in this case entered twice—once in the second square from the left of the top row, as being a first class man with a second class brother, and once in the third square of the same row as having a third class brother; but if both *Y* and *Z* had been in the second class he would have been entered twice in the second square. Similarly *Y* is entered once in the left hand square and once in the third square of the second row, and *Z* is entered once in the left hand square and once in the second square of the third row. Thus the family of three contributes $3 \times 2 = 6$ to the total number, a family of four, $4 \times 3 = 12$, of five, $5 \times 4 = 20$, and so on; so that the total 4266 does not represent 8532 men taken together two by two as might possibly have been supposed, but 4266 pairs made from a smaller number of men. It will be noticed as a result of this method of construction, the table is symmetrical about an axis which runs from the left hand top corner to the right hand bottom corner.

If to begin with we examine this table in the same way in which the examination of Tables I A. and II A. was begun, we shall see that out of the 339 first class men reckoned in the way described above, 154 or 45·5 per cent. had brothers in the first and second classes; of the 668 second class men, 254 or 38 per cent. had brothers attaining this standard; and that the percentages diminish steadily and fairly rapidly as we pass down our scale of classes to 27·6 per cent. for the third class men, 21·2 per cent. for the fourth class men, 15·3 per cent. for the pass

men and 12·6 per cent. for those who obtained no degrees. If we compare this series with the corresponding one obtained from Table I A. we shall see a well-marked general similarity between the two, but, although the percentage of first and second classes among the brothers of the men who failed to take degrees is practically identical with that among the fathers, it is considerably higher among the brothers than among the fathers of first class men; so that we can conclude from this alone that the resemblance between brother and brother is more marked than that between father and son; and it will be seen when we come to treat the contingency and correlation coefficients that the same result is obtained from them also.

It will be unnecessary to consider separately the Tables V A. and VI A.; the former is made from those families in which the majority of brothers took their degrees between 1830 and 1860, and in the latter those between 1800—1830 were used; a few individual brothers in this case did actually take their degrees later than 1830 and thus were capable of obtaining fourth class honours, but very few were so placed, and as the number of these was so small, in making the table it was not thought worth while to treat them separately and they were included among the pass degree men.

For all the three sets of material included in Tables IV A., V A. and VI A. respectively, the mean square contingency coefficient and the mean contingency coefficient were calculated, and in order to obtain various values for the correlation coefficient the original tables were simplified in different ways. Thus in constructing Tables IV B., V B., and VI B., divisions both vertical and horizontal were made in IV A., V A., and VI A., between the second and third classes and all the numbers in each of the four divisions of these tables thus defined were added together; to make Tables IV C., V C., and VI C. the original tables were divided between the third and fourth classes; and Tables IV D. and V D. were made by simply separating honours men from the rest. The results of all these variations in method are summarized in Table VII. From this it will be seen that all the correlation coefficients agree tolerably well together, and all the mean square contingency coefficients agree together exceedingly well, but that the latter do not agree with the former, being in each case considerably less, and it will be remembered that a difference in the same direction but not nearly so well marked was noticed with regard to the tables dealing with the fathers and sons, the results of which are summarized in Table III.

D. *The Influence of Family Traditions on the Results obtained.*

The differences that are pointed out in the preceding paragraph between the mean square contingency coefficients and the correlation coefficients are probably due to the fact that the material is not homogeneous, that is to say that each

table is in reality made up of two groups of men, whose success in the examination is determined by two different sets of circumstances. The first and probably the larger of the groups consists of those men who were really placed according to their merits, and consists of all those who tried for honours, whether they obtained them or not, together with those who refrained from trying because it was recognized by themselves or their tutors that they were not up to the honours standard. The other group consists of such men as did not try for honours although of sufficient intellectual capacity. As family circumstances or family tradition influence a man when he decides for what kind of degree he shall become a candidate, in that he is more likely only to aim at a pass if his father or elder brother should have done so before him, we shall get an excess of pairs of fathers and sons or brothers and brothers who have each taken pass degrees, beyond what might normally have been expected, if every man were classed entirely on his own merits. The effect of this excess is to increase the size of the correlation coefficients and thus to give a greater appearance of inheritance of ability than would be manifested if it were not present, also to spoil the agreement between the contingency coefficients and the correlation coefficients.

The difference between these two is greater in the tables dealing with resemblance between brother and brother than in those dealing with that between father and son, so that we may conclude that the example of his brother has more influence on a man's choice whether or no he shall try for honours than that of his father, or at any rate that there are more common circumstances influencing the choice of each of a pair of brothers than of a father and his sons. This conclusion is in accordance with one's personal experience and we shall adduce other arguments to support it.

If in making the tables we could have separated the two groups of men distinguished above, the consideration of the question would have been greatly simplified. Unfortunately it was impossible to do this, but in order to obtain a rough idea of the influence of family tradition on our results the following test has been applied to our tables. A vertical strip consisting of the three right-hand columns* of Tables I A. and V A., and of the two right-hand columns of Tables II A., IV A., and VI A., was cut off in each case, thus leaving in the tables only those pairs of which one member at least tried for honours. In this way the possibility of including any man in the tables who took a pass degree merely because—in the case of Tables I A. and II A.—his father did, or—in the case of Tables IV A., V A., and VI A.—because his brother did, is entirely eliminated. Fourfold correlation tables were then constructed out of the portions of the tables that were left, and the results for each table were as follows:

* It was necessary to remove the fourth class column, because these fourth classes were obtained during a period in which a regulation was enforced allowing the Examiners to place in the fourth class of honours any candidate for a pass degree, who was considered worthy of honours.

Table I A., after the three right-hand columns had been removed from it, which contain all the sons who had fathers in the fourth class or who had taken pass degrees or no degrees, gave a mean value for the correlation coefficient of ·245, a result derived from fourfold tables made in two different ways. The fathers were in both cases divided into two groups, the one containing the first and second classes, the other the third class, and the sons being in the one case divided into two groups by a line drawn below the second class and in the other below the third class. It will be remembered that the original mean value obtained for the correlation coefficient was ·290.

From Table II A. the two right-hand columns were removed which contained those sons whose fathers had taken pass degrees or no degrees. From what was left fourfold tables were constructed in two different ways; in both cases the fathers were divided into two groups containing on the one hand the first class, and on the other the second and third classes, and the sons were divided in the first table by a line drawn below the third class and in the second below the fourth. The mean value of the two correlation coefficients was ·200, as against ·335 obtained from the original table.

The three tables IV A., V A., and VI A. dealing with fraternal correlation were treated in an analogous way and gave mean values for the correlation coefficients of ·235, ·175 and ·255 respectively, as against ·393, ·397 and ·425 obtained from the original tables. Thus it will be seen that the process applied brings about a great reduction in the value of the correlation coefficients, and that this reduction is more conspicuous in the tables dealing with brother and brother than in those dealing with father and son. It is the latter circumstance which confirms our conclusion stated previously that tradition and other external causes are more potent in magnifying the appearance of heredity in the fraternal groups than in the paternal.

It must not be supposed that the reduced values are to be regarded as the true measures of the intensity of the purely hereditary influence, after an allowance has been made to counteract that of tradition, because even if the latter had been absent altogether in the first instance the effect of cutting off strips from the correlation table would have had the effect of reducing the value of the coefficients. But the process adopted does show that, after making an allowance for tradition which certainly very much *more* than counteracts it, it is still possible to detect a very considerable hereditary influence.

In order to give further support to the contention that the method of correction employed gives a greatly *exaggerated* estimate of how much of our results are due merely to tradition, let us turn for a moment to Table V D., which deals with those pairs of brothers who took their degrees between the years 1830—1860, in which the divisions are made between the fourth class men and the pass men. Now the results obtained from this table should be influenced less by

tradition than those from any of the other fourfold tables dealing with fraternal correlation, because during this period all men, whether candidates for honours or not, were examined by the same set of examiners, and those who were considered worthy of honours were given them, though if they were only aiming at a pass degree they were not in any case placed higher than the fourth class. Thus a division between honours and no honours is probably a much better twofold division according to merit than any other which has been made in the tables, and consequently the effects of tradition on the results cannot be so great. If the effects of tradition in increasing the correlation coefficients are in reality very great, the correlation coefficient obtained from a table, in which they are known to be at any rate comparatively small if not entirely absent, should be markedly lower in value than those obtained from the other tables; instead of this we find that Table V D. gives a value of ·43, which is actually higher than the majority.

From the considerations detailed above we must conclude that tradition has some effect in increasing the apparent strength of heredity as measured hitherto in this paper, but that it is not so great an effect as might have been supposed and that it changes the fraternal coefficients more than it does the paternal.

E. *Conclusions.*

To return to the actual values obtained from the Oxford records, the mean value obtained for the fraction expressing the degree of resemblance between father and son, as deduced from the five correlation coefficients calculated, is ·312, and that between brother and brother, from the eight coefficients calculated, ·405. We will now compare these figures with corresponding ones calculated for easily and accurately measurable physical characters; a large number of these will be found in the paper "On the Laws of Inheritance in Man," by Professor Pearson and Miss Alice Lee (*Biometrika*, Vol. II. p. 357). If we select from all these those that deal with father and son, and brother and brother, we get the following results:

Correlation between	father and son	brother and brother
Stature	·514	·511
Span	·454	·549
Length of Forearm	·421	·491
Mean	·463	·517
Oxford Class Lists	·312	·405

It will be noticed that the mean values obtained from the Oxford class lists are in both cases lower than the mean values given for physical characters. But

in spite of the slight artificial raising of the former, which we have dealt with in the preceding section, it is only to be expected that they should be lower than the latter, even if they are the statistical expression of an intensity of inheritance of mental ability really of the same degree as that of the three physical characters referred to.

The reason for this is that, although a skilfully conducted examination lasting for four or more days is likely to give a reasonable estimate of a man's ability, yet serious mistakes are frequently made, so that it cannot be claimed that such an estimate is nearly as accurate as careful measurements of stature, span or length of forearm. It is also a matter of fact and not of theory or surmise that when the correlation coefficient between two variables is calculated, the nearer the measured value of each is to its true value, that is to say the more accurately each is measured, the higher the value of the coefficient will be; provided always that the error in the measure of the one variable is quite independent of that in the other. In the case of our own tables dealing with the classes obtained by fathers and sons, the one variable is the class obtained by the father and the other associated variable is the class obtained by his son. In some cases a father whose real ability may entitle him to one particular class, say the second, is placed wrongly, say in the third or fourth class; now if his sons are also intellectually entitled to a particular class, and the fact that their father has been placed erroneously below his proper class has no influence whatever in lowering the class in which they themselves are placed, then the values of the correlation or contingency coefficients obtained will be lower than they would be if in all cases both father and sons had been correctly placed. Since it is difficult to imagine that an error in the placing of the father could have any effect on the placing of the sons, so we argue from this that our coefficients have been lowered by the mistakes of the examiners, and therefore our results are not incompatible with the conclusion reached by Professor Pearson in his Huxley Lecture (*Biometrika*, Vol. III. p. 156) that "the physical and psychical characters in man are inherited within broad lines in the same manner and with the same intensity."

One point further must be referred to, namely the relative value of the paternal to the fraternal correlations. The mean value for the former for the physical characters which we have quoted is ·463 and for the latter ·517, thus they bear to one another the relation of 1 to 1·12; our own values are respectively ·312 and ·405, which bear to one another the relation of 1 to 1·30. Thus it will be seen that the relative value of fraternal to paternal correlation is larger in the case of examination results than of physical characters, being 1·30 instead of 1·12. This is quite in accordance with expectation if the conclusion, previously expressed, be correct, that tradition and other external causes have more effect in raising the fraternal coefficient than the paternal.

PART II.

THE EVIDENCE OF THE HARROW AND CHARTERHOUSE SCHOOL LISTS.

A. *Harrow.*

We owe the material on which this section is based to the kindness of Mr M. G. Dauglish, an old Harrovian and the editor of the *Harrow Register*. This work gives a list of all who entered the school from 1800—1900, which is probably perfectly complete and correct from the commencement of Dr Vaughan's headmastership in 1845; a short biographical notice of each name is given, including the father's name and the date of entry into the school. The position in the school of each boy included in our tables was ascertained from the four volumes of the *Harrow Calendar*, which are practically a reprint of the "Bill Books" from 1845—1891. It is perhaps necessary to explain that the "Bill Books" are lists published each term of all the boys in the school, arranged according to their position in the school. The "Blue Books" give the names in alphabetical order, but put the name of the class in which the boy is placed after each name. The last two volumes of the *Harrow Calendar* are indexed but the first two are not, so that both the labour of finding a boy's position in the school and the chance of errors in doing so are considerable, but as in making the tables those boys who came before 1858 are not used, only a small percentage occur in these first two volumes. In order to bring the list from 1891 up to date, a complete set of "Bill Books" and "Blue Books" from 1892 onwards was procured from the publisher, J. C. Wilbee, of Harrow.

After having made lists, as complete as possible, of all the sets of brothers who entered the school from 1858 onwards, their position in the school for comparable times in their careers was found out for each boy. As the dates of birth are not given in the register, but only the date of entry into the school, it was decided to take for the first fixed point the summer term following their year of entry, which was called year 1. The boy's position was found for this year and for the summer term in each subsequent year in which he remained in the school, which were called respectively year 2, year 3 and so on. These particulars were entered on slips of paper, one slip for each fraternity, which were sorted into two groups, one dealing with the earlier entries and one with the later. The former includes all those containing one member who entered the school in the years 1858—1870, although some of its members may have

entered the school later; the latter contains only those families of which no member entered before 1871, and it is with this group we deal first. Apart from the modern side, the divisions of which were difficult to bring into line with those of the rest of the school and which therefore are not included in the table, the school consisted in the summer of 1875 of the following divisions: (1) monitors, of whom nearly all were above the upper sixth, but possibly one or two in the upper or lower sixth; (2) upper sixth; (3) lower sixth. These together formed the uppermost of the seven main divisions of the school used in the tables; they contained in all 68 boys or 13·82 per cent. of the school; then came the fifth, divided into three divisions, an upper, middle and lower, of which the first two form our second division, consisting of 67 boys or 13·62 per cent. of the school; our third division includes the third division of the fifth and the upper division of the next form, the remove, and consists of 64 boys or 13·00 per cent., while the lower division of the remove, sub-divided for purposes of school work into two parallel classes, formed our fourth division, which consists of 72 boys or 14·63 per cent. of the school; our fifth division contained the upper shell, which like the lower remove was sub-divided into two parallel classes; this contained 71 boys or 14·43 per cent., while the middle and lower shells comprising 67 boys or 13·62 per cent. of the school formed our sixth division; and our seventh and last comprised the upper, middle and lower fourth, and contained 83 boys or 16·87 per cent. of the school. Thus it will be seen that for the purposes of our tables we have divided the school into seven roughly equal divisions, using the natural boundaries provided by the school classes; these seven divisions with practically the same boundaries remain approximately equivalent for the whole period of time covered by the later group. The three principal tables dealing with this group, VIII A., IX A., and X A., were made in precisely the same way as Tables IV A. and V A., which refer to the Oxford pairs of brothers, so it will be unnecessary to describe the details of their making. In Table VIII A. the boys are classed according to their position in year 1, that is to say in the summer term following their admission to the school. 637 families of brothers were used in making this table, of which 454 were families of 2, and thus contributed 908 pairs to the table, 128 were families of 3 and supplied 768 pairs, while the remainder of the total number of 2540 was made up of 432 derived from 36 families of 4, 300 derived from 15 families of 5, 90 derived from 3 families of 6, and 42 derived from one family of 7. For making Table IX A. where a classification according to the position in year 2 was used, the number of available families had sunk, owing to boys leaving or going on to the modern side, to 485, and as this was comprised of 342 families of 2, 104 families of 3, 27 families of 4, 9 families of 5, and 3 of 6, the total number of pairs was 1902. In the same way Table X A. deals with year 3; here we find that of the original 637 families only 350 were left, 262 of 2, 62 of 3, 18 of 4, 6 of 5, and 2 of

6 brothers, making in all 1292 pairs. When we came to the fourth year the number of families had sunk so low that it was not thought worth while to include them in this paper.

It would perhaps be as well at this point to enumerate briefly the results obtained from these three tables, reserving our comments on them for a later period. Firstly the mean square contingency coefficient (C_1) and the mean contingency coefficient (C_2) were calculated for each of them and the following values obtained, for VIII A., $C_1 = \cdot 39$, $C_2 = \cdot 38$; for IX A., $C_1 = \cdot 37$, $C_2 = \cdot 39$; for X A., $C_1 = \cdot 39$, $C_2 = \cdot 38$. The 49 divisions of each table were then reduced in two different ways to 4. Thus Table VIII A. provided Tables VIII B. and C.; in the former the divisions were taken between the upper and middle shells, and in the latter between the lower remove and upper shell. A value for the correlation coefficient r of ·28 was obtained from Table VIII B. and of ·36 from VIII C., the mean of the two being ·320. In deriving Table IX B. from IX A. those in the upper remove and above were separated from those in the lower remove and below, while in Table IX C. the dividing line was taken below the second division of the fifth. These tables give values of r of ·25 and ·46 respectively, averaging ·355. Tables X B. and X C., made from Table X A. by dividing it in the first case below the second division of the fifth and in the second case below the upper remove, give values of r of ·28 and ·35 of which the mean is ·315.

Having thus described the methods of treatment of, and the results obtained from the later group, we will turn our attention to the earlier one. It was not so easy in this case as in the last to obtain seven divisions of the school, which remained approximately equivalent during the whole period treated of, owing to a curious practice, which is also observable in the Charterhouse lists, of abolishing forms at the bottom of the school, and of inserting fresh ones in the middle. The apparently illogical nomenclature of school classes forms a sort of fossilized record of this practice. Thus at the present day both at Harrow and at Charterhouse the highest form with a numerical name is the sixth and the lowest is the fourth. Thirds, seconds and firsts have existed, but have been abandoned one by one even during rapid and continuous growth of the school, and their places have been taken by removes and shells thrust in between the older forms and by repeated sub-divisions of the latter. We are not concerned to find reasons for this practice, but since it added considerably to the complications of our task we were obliged to note it and deplore it.

In making our seven divisions in order to construct tables from the earlier material the first three are identical with the first three of the later group, except that as between 1865—1872 for what was formerly called the fourth division of the fifth another form (the upper remove) equivalent in position and size was substituted, so that before this change was made our third division consisted of the third and fourth divisions of the fifth, instead of the third division of the

fifth and the upper remove. With regard to our fourth division in 1859—1864 the remove taken together with the first division of the shell was found to be more nearly equivalent to the remove of later days than either of these classes taken separately; similarly in our fifth division, as there were four divisions of the shell up to 1872, each of them being single divisions (*i.e.* not sub-divided into two parallel classes), the first and second divisions are equivalent to the upper shell of 1873 and onwards, and to the second and third divisions of the same class in 1864 and earlier. For our sixth division the fourth division of the shell and the first division of the fourth, from 1859—1864, taken together are approximately equivalent to the third and fourth divisions of 1865—1872, and to the middle and lower shells of 1873 and onwards. For the seventh, all that was lower than the sixth was in each case included, an assortment which included a greatly shrunk third class for the first few years, until that relic was finally abandoned.

To turn to results. Table XI A. deals with the position of the brothers in year 1 and gives a value for the mean square contingency coefficient (C_1) of ·38 and for the mean contingency coefficient (C_2) of ·45; while converted into the fourfold table (XI B.) by dividing between our fifth and sixth divisions both vertically and horizontally it gives a value for the correlation coefficient (r) of ·44, or if the partitions are made between our fourth and fifth divisions (Table XI C.) of ·45. From Table XII A. in which the grouping is made according to the position of the brothers in year 2, C_1 was found to be ·39 and C_2 ·45; while the two values of r obtained by separating the table into four compartments by partitions between our third and fourth divisions as in Table XII B., and between our second and third as in Table XII C., are respectively ·45 and ·37. Table XIII A. is based on the position of the brothers in year 3; from it a value for C_1 of ·38 can be obtained and for C_2 of ·45. Table XIII B. is derived from Table XIII A. by separating it between our second and third divisions and gives a value for r of ·49, while from Table XIII C., in which the separation was made between our third and fourth divisions, the value of r was found to be ·42. We will not stop to discuss the significance of these results in this place, but will defer the consideration till we have those obtained from the Charterhouse lists for comparison.

B. *Charterhouse.*

The Charterhouse results are based on the names included in the *Charterhouse Register*. This work gives short biographical notices of all those who came down with the school in its move from Smithfield to Godalming in 1872 and of all who entered it since that date. Unfortunately the notices omit the names of the fathers, which should be considered an essential part of any biography, however short. It is earnestly to be hoped that this omission may be rectified in future editions, as the name of the father is most useful in identifying undistinguished people, who

are not labelled with any position or achievements of note. It is only through the kindness of Mr O. H. Latter, of Charterhouse, that we were enabled to do the work at all, for he supplied us with the particulars of all, or nearly all, those families of brothers whose names are included in the *Register*. To do this entailed on him an enormous amount of work, for which we wish to express to him our most sincere gratitude. On the recommendation of Mr Tod, of Charterhouse, one of the editors of the *Register*, we used, for finding the position of the brothers in the school at different ages, the Charterhouse "Blue Books"; and we have to thank Dr Rendall, the headmaster, for allowing us to be supplied from the school stationery shop with a complete set of these from 1872 onwards. These "Blue Books" are quite unlike the Harrow "Blue Books" in plan; they are printed once a year and give the names of the boys arranged in their forms and the results of the yearly examinations, which take place at the end of the cricket quarter. Since the date of the birth of each boy is given in the *Register*, it was possible to find from the "Blue Books" the form in which he was in the summer term of the year in which he reached any given age. The ages chosen in making the three contingency tables which are included in this paper are 15, 16, 17, as it was found that these were the three most common ages. As in the case of the Harrow tables, we have divided the school forms into seven groups, which we have tried to make as nearly as possible equivalent during the whole period covered. This necessitated a different grouping for every year for the first seven years, 1872—1878, as very rapid changes in arrangement took place during this period, but from 1881 the forms have remained practically the same, so that we have used the same grouping from that year onwards. It is as follows: A first division containing the sixth and under sixth forms and also the middle sixth on its introduction in 1896; second, third, fourth, fifth, sixth and seventh divisions made up of the fifth forms, remove, upper fourth, middle fourth, under fourth, and shell respectively. Our first division remained the same as far back as 1876, but in 1875 the first class of the fifth was added to it, and in 1872—1874, when there was no under sixth, the second class of the fifth was also included. If we follow our second division backwards we find it remaining the same till 1877, but in that year and in 1876 we included also the remove. In 1875, when the first class of the fifth had to be taken away in order to add it to the first division, the first class of the upper fourth was moved up to take its place; in 1874, as the second class of the fifth was also used in the same way, the whole of the upper fourth was included; and in 1872 and 1873, before the remove had come into existence, the whole of the upper and lower fourth. Our third division, which consists of the remove from 1878 onwards, was made up of the upper fourth in 1876 and 1877, of classes II. and III. of the upper fourth and of the under fourth in 1875, of the under fourth and classes I., II. and III. of the upper shell in 1874, of the upper shell and classes I. and II. of the under shell in 1873, and of the shell

in 1872, a class which forms the bottom of the school from 1878 onwards. Our fourth division, which was made up of the upper fourth from 1878 onwards, consisted of the under fourth only in 1876 and 1877, of the upper shell in 1875, of class IV. of the upper shell, of the middle shell and under shell in 1874, of classes III. and IV. of the under shell and of the upper third in 1873, and of the third form in 1872. Our fifth division consisted of the middle fourth form from 1881 onwards, the under fourth from 1878—80, the upper shell in 1876 and 1877, of the under shell and classes I. and II. of the upper third in 1875, of the upper third and classes I., II. and III. of the middle third in 1874, of the under third in 1873 and of the second form in 1872. Our sixth division was made up of the under fourth from 1881 onwards, of the upper shell from 1878—80, of the under shell in 1877, of the under shell and upper third in 1876, of classes III. and IV. of the upper third and middle third in 1875, of class IV. of the middle third, of the under third and classes I. and II. of the upper second in 1874, of the second form and class I. of the first form in 1873 and of the first form in 1872. Lastly the following forms were left over for the seventh division: In 1881 and onwards the shell, in 1878—80 the middle and under shells, in 1877 the third form, in 1876 the middle third, in 1875 the under third, in 1874 class III. of the upper second and the under second, in 1873 classes II. and III. of the first, and in 1872 a class which was placed below the first and called the Petties.

In Table XIV A. the material is grouped according as the brothers were in one or other of the seven divisions of which the limits are described above, during the year in which each reached the age of 15. The mean square contingency coefficient (C_1) calculated from this table is ·38 and the mean contingency coefficient (C_2) ·40, and the values of the correlation coefficient (r) are ·43 and ·41, according as the boundaries of the fourfold table are taken just above (Table XIV B.) or just below (Table XIV C.) the fourth division. In Table XV A. the positions of the brothers in the years in which they reached 16 are used. It gives a value of ·44 for C_1 and of ·46 for C_2, while from the fourfold table which is derived from it by putting the first and second divisions on the one hand and the third to the seventh on the other (Table XV B.) a value for r of ·47 can be calculated, while if the third division is included with the first and second (Table XV C.) the value is ·46. In making Table XVI A. the position of the brothers in the year in which they reached the age of 17 is used. From it values of C_1 and C_2 of ·44 and ·43 respectively are obtained, and from Tables XVI B. and C., which correspond exactly with Tables XV B. and C., values for r of ·48 and ·32 can be calculated.

C. *Conclusions.*

The statistical constants obtained from the consideration of the Harrow and Charterhouse brothers will be found summarized in Table XVII.; in the first column the mean square contingency coefficients are given. In glancing down this it will be found that they vary from ·37 to ·44, with a mean value of ·395. The mean contingency coefficients, which are set forth in the second column, are slightly more variable—·38 to ·46—and their mean value is ·415. The correlation coefficients show a far wider variability—·25 to ·49—but their mean value ·398 approaches very closely to that of the mean square contingency coefficient. It will be noticed that the values obtained for the correlation coefficients from the later of the two Harrow groups, given first in Table XVII., are markedly less than those obtained either from the earlier Harrow group or from Charterhouse, and as this difference is shown in each of the three tables one would be inclined to attach more importance to it than that to which in our opinion it is entitled. But it must be remembered that practically all the boys included in the tables relating to the third year are also included in those which relate to the second year, and similarly the material of the second year tables is also included in the first. Thus the results obtained from one year do not give much additional weight to those obtained from another, as would be the case if the material used in each was absolutely independent. Another reason for not attaching undue weight to the small value of these correlation coefficients is that they are very much less than the mean square contingency coefficients of which the average for this group is ·383, whereas the average of the correlation coefficients is ·330. We must therefore conclude that it is due to some abnormality of this particular material, a conclusion which is confirmed by the great difference between the two correlation coefficients for year 2 (·25 and ·46). The other differences visible in the table are probably well within the limits of the agreement which can be expected from this class of work. But we hold that the average values of the different constants, which will be found in the last line of Table XVII., may be taken as fairly accurate measures of the resemblance of one brother to another as shown by their position in school at corresponding ages, or at corresponding points in their school careers. They agree very well with one another and with the measure of fraternal resemblance obtained by the four square correlation method from the Oxford material, which on referring to Part I. will be found to be ·401. Like that number they must be considered to be minimum values, for, although it may be held that position in school affords a more accurate indication of mental worth than the result of a single examination, yet other disturbing factors creep into the consideration of the school results which do not exist or exist only in much lesser degree in the arguments

from the University lists. Thus both at Harrow and at Charterhouse the position was only taken at one point in the year, namely the summer term, therefore in the former case, as boys came to the school also in the Easter and autumn terms, there must be about eight months' difference in the length of time during which they had stayed at the school between the senior and the junior boy; and in the latter case, as boys are born at any time during the year, there is probably a year's difference in age between the oldest and youngest boy included in any one table, and eight months of school life or a year of one's age makes a considerable difference to one's position in the school. Apart from this, although the usual age for entering a public school is between the thirteenth and fourteenth birthdays, some boys enter earlier and some later. Thus in the Harrow tables there may be a fairly wide variation of age between all the boys who had been at the school a given length of time, and in the Charterhouse tables the same variation may occur in the length of time they had been in the school of all the boys of a given age. Since both his age and the length of time a boy has been in the school are factors affecting his position in it, it would appear at first sight that this variability would reduce the value of the contingency and correlation coefficients, and inasmuch as there is variability in this respect within each family, or at any rate within some of the families taken separately, it must undoubtedly do so. But it is probable that in some cases a parent sends all his sons to school either rather earlier or rather later than the average, and as this would have the effect of increasing the value of the coefficients, it is probable that the variation of the age of entry of the boys does not affect the results to any serious extent either one way or the other.

It will no doubt occur to our readers that the brain power of a boy at a given age depends on the rate at which his intellect developes besides his natural ability, and that we have left the former of these two factors out of consideration, although in all probability it varies as much as the latter. We do not think that our results are in any way spoilt by this, for, although it cannot be questioned that what we have measured is a character compounded of the two, yet, as there is no reason to suppose that either of them is inherited in a different way from the other, what is a measure of the inheritance of the combination is probably also a measure of the inheritance of each separately.

One more circumstance must be mentioned which tends to reduce the value of the fraternal coefficients. As all who were sons of the same father are included in the tables, and as the mothers were in no case known, a certain number of half-brothers are included as brothers, and as the correlation between half-brothers cannot be so high as that between brothers this admixture would have the effect of slightly diminishing the coefficients.

Having reviewed circumstances tending in the direction referred to above, we must say something of those which tend in the other direction, namely to increase

the size of the coefficients. The most obvious of these is the similarity of environment of different members of the same family; we can only say that we have reduced this as far as possible by taking only members of the same school or University together, yet it cannot be denied that home influences and previous education must have a certain effect and that this effect will be in the direction named. Yet it appears to us that the action of this factor must diminish in intensity as the boy grows older, for the similarity between the education of the different families becomes more and more complete as they spend more and more time in the same school under the same conditions. If therefore this factor has any serious effect on the results, we should look to see a steady diminution in the size of the coefficients as we pass from year 1 to year 2 and from year 2 to year 3 in the Harrow tables, and from age 15 to age 16 and to age 17 in the Charterhouse ones. Reference to Table XVII. shows us that no diminution of this kind does in reality exist, and thus we argue that the effect of environment is less than might have been supposed.

We must confess that we found it impossible to eliminate all spurious correlation, for in each case the relative values of the different classes have changed somewhat during the periods covered in the tables, the change being mostly in the direction of the increase in the size of the upper divisions; in this way towards the end of the period a slightly greater percentage of pairs of brothers must have been entered in the squares near the left hand top corner of the tables than at the beginning. The effect of this is to increase the size of the contingency and correlation coefficients. As however we were at pains to reduce this as much as possible by adjusting the school classes in the ways described, we hope and believe that our results are not seriously disturbed by it.

Summary of Results.

We started with the intention of measuring as exactly as possible the resemblance between father and son and brother and brother, as shown by their successes or failures in passing the examination for the B.A. degree at Oxford or by their position in school at Harrow and Charterhouse at corresponding times; and we stated that complete resemblance would be indicated by unity, and no resemblance at all by 0, the various degrees of partial resemblance by fractions lying between 0 and unity. We denoted, with references, the methods employed in doing this, namely the contingency method and the fourfold correlation method, and we gave reasons why reliance should be placed, when dealing with the Oxford material, on results obtained by the latter rather than by the former of these. These results were for the correlation between father and son ·312 and between brother and brother ·405. Dealing with the public school material it was impossible to compare father and

son, so that only the correlation and contingency coefficients between brother and brother were calculated; the mean value obtained from all the tables for the former was ·398, which shows a remarkably close agreement with that obtained from the Oxford material, ·405, and also agrees with the mean values of the contingency coefficients ($C_1 = ·395$, $C_2 = ·420$). We endeavoured to show why the values should be considered as minimum values; we argued from this that they are not incompatible with the conclusion reached by Professor Pearson in his Huxley Lecture before the Anthropological Institute (*Biometrika*, Vol. III., p. 156) "that the physical and psychical characters in man are inherited within broad lines in the same manner and with the same intensity."

In conclusion, we must express our sincere thanks to Mr Galton and to Professor Karl Pearson for the most valuable help and advice which they have given us.

TABLE I A. *Date of Son's Degrees*, 1861—92.

Fathers

Sons		Honours: First Class	Honours: Second Class	Honours: Third Class	Honours: Fourth Class	Pass Degree	No Degree	Totals
Honours	First Class	27	27	14	13	53	15	149
Honours	Second Class	52	54	33	30	138	22	329
Honours	Third Class	47	64	47	42	157	20	377
Honours	Fourth Class	20	27	22	17	91	13	190
Pass Degree		41	79	95	87	479	87	868
No Degree		31	39	46	52	277	101	546
Totals		218	290	257	241	1195	258	2459

$C_1 = \cdot 26$, $C_2 = \cdot 29$.

TABLE I B.

Fathers

Sons	Honours Classes I & II	Honours Cl. III & IV, Pass Degree, No Degree	Totals
Honours Classes I & II	160	318	478
Honours Classes III & IV, Pass Degree, No Degree	348	1633	1981
Totals	508	1951	2459

$r = \cdot 29$.

TABLE I C.

Fathers

Sons	Honours Classes I, II & III	Honours Class IV, Pass Degree & No Degree	Totals
Honours Cl. I, II & III	365	490	855
Honours Class IV, Pass Degree & No Degree	400	1204	1604
Totals	765	1694	2459

$r = \cdot 30$.

TABLE I D.

Fathers

Sons	Honours Classes I, II, III & IV	Pass Degree & No Degree	Totals
Honours Classes I, II, III & IV	536	509	1045
Pass Degree & No Degree	470	944	1414
Totals	1006	1453	2459

$r = \cdot 28$.

TABLE II A.

Fathers

Sons		Honours: First Class	Honours: Second Class	Honours: Third Class	Pass Degree	No Degree	Totals
Honours	First Class	20	16	9	27	14	86
	Second Class	32	27	15	60	11	145
	Third Class	22	15	19	46	9	111
	Fourth Class	11	18	16	45	13	103
Pass Degree		67	74	75	371	113	700
No Degree		20	30	30	184	122	386
Totals		172	180	164	733	282	1531

$C_1 = \cdot 29, \qquad C_2 = \cdot 31.$

TABLE II B.

Fathers

Sons	Honours Classes I & II	Honours Class III, Pass Degree, No Degree	Totals
Honours Classes I & II	95	136	231
Honours Classes III & IV, Pass Degree, No Degree	257	1043	1300
Totals	352	1179	1531

$r = \cdot 34.$

TABLE II C.

Fathers

Sons	Honours Classes I, II & III	Pass Degree & No Degree	Totals
Honours Cl. I, II & III	175	167	342
Honours Class IV, Pass Degree & No degree	341	848	1189
Totals	516	1015	1531

$r = \cdot 33.$

TABLE III.

Measures of Resemblance between Father and Son, found by different methods.

Date of Degrees taken by Sons	C_1 = Mean square Contingency Coefficient	C_2 = Mean Contingency Coefficient	r = Correlation Coefficient found by the 4-fold Correlation Method			Mean of r's
			found from Table I C.	found from Table I D.	found from Table I E.	
1860—1892	·26	·29	·29	·30	·28	·290
			found from Table II B.	found from Table II C.	—	
1830—1860	·29	·31	·34	·33	—	·335

TABLE IV A. *Date of Degree*, 1860—1892.

Second Brother		First Brother: Honours — First Class	Honours — Second Class	Honours — Third Class	Honours — Fourth Class	Pass Degree	No Degree	Totals
Honours	First Class	56	98	59	18	70	38	339
	Second Class	98	156	148	54	136	76	668
	Third Class	59	148	166	72	200	105	750
	Fourth Class	18	54	72	32	103	60	339
Pass Degree		70	136	200	103	576	260	1345
No Degree		38	76	105	60	260	286	825
Totals		339	668	750	339	1345	825	4266

$C_1 = ·32, \qquad C_2 = ·39.$

Table IV B.

First Brother

Second Brother	Honours Classes I & II	Honours Classes III & IV, Pass Degree & No Degree	Totals
Honours Classes I & II	408	599	1007
Honours Classes III & IV, Pass Degree & No Degree	599	2660	3259
Totals	1007	3259	4266

$r = .38$.

Table IV C.

First Brother

Second Brother	Honours Classes I, II & III	Honours Class IV, Pass Degree & No Degree	Totals
Honours Classes I, II & III	988	769	1757
Honours Class IV, Pass Degree, No Degree	769	1740	2509
Totals	1757	2509	4266

$r = .40$.

Table IV D.

First Brother

Second Brother	Honours Classes I, II, III & IV	Pass Degree & No Degree	Totals
Honours Classes I, II, III & IV	1308	788	2096
Pass Degree & No Degree	788	1382	2170
Totals	2096	2170	4266

$r = .40$.

TABLE V A. *Date of Degree*, 1830—1860.

First Brother

Second Brother		Honours: First Class	Honours: Second Class	Honours: Third Class	Honours: Fourth Class	Pass Degree	No Degree	Totals
Honours	First Class	68	48	31	31	81	28	287
	Second Class	48	72	46	44	127	48	385
	Third Class	31	46	36	33	110	41	297
	Fourth Class	31	44	33	44	120	53	325
Pass Degree		81	127	110	120	856	357	1651
No Degree		28	48	41	53	357	178	705
Totals		287	385	297	325	1651	705	3650

$C_1 = \cdot 30, \quad C_2 = \cdot 36.$

TABLE V B.

First Brother

Second Brother	Honours Classes I & II	Honours Cl. III & IV, Pass Degree, No Degree	Totals
Honours Classes I & II	236	436	672
Honours Classes III & IV, Pass Degree, No Degree	436	2542	2978
Totals	672	2978	3650

$r = \cdot 37.$

TABLE V C.

First Brother

Second Brother	Honours Classes I, II & III	Honours Class IV, Pass Degree, No Degree	Totals
Honours Cl. I, II & III	426	543	969
Honours Class IV, Pass Degree & No Degree	543	2138	2681
Totals	969	2681	3650

$r = \cdot 39.$

TABLE V D.

First Brother

Second Brother	Honours Classes I, II, III & IV	Pass Degree & No Degree	Totals
Honours Classes I, II, III & IV	686	608	1294
Pass Degree & No Degree	608	1748	2356
Totals	1294	2356	3650

$r = \cdot 43.$

TABLE VI A. *Date of Degree*, 1800—1830.

First Brother

Second Brother		Honours: First Class	Honours: Second Class	Honours: Third Class	Pass Degree	No Degree	Totals
Honours	First Class	56	34	26	71	24	211
	Second Class	34	28	32	100	38	232
	Third Class	26	32	40	127	33	258
Pass Degree		71	100	127	832	360	1490
No Degree		24	38	33	360	226	681
Totals		211	232	258	1490	681	2872

$C_1 = \cdot 31, \qquad C_2 = \cdot 29.$

TABLE VI B.

First Brother

Second Brother	Honours Classes I & II	Honours Cl. III & IV, Pass Degree, No Degree	Totals
Honours Classes I & II	152	291	443
Honours Classes III & IV, Pass Degree, No Degree	291	2138	2429
Totals	443	2429	2872

$r = \cdot 42.$

TABLE VI C.

First Brother

Second Brother	Honours Classes I, II & III	Honours Class IV, Pass Degree & No Degree	Totals
Honours Cl. I, II & III	308	393	701
Honours Class IV, Pass Degree & No Degree	393	1778	2171
Totals	701	2171	2872

$r = \cdot 43.$

Table VIII A.

First Brother

Second Brother	Sixth	First and Second divisions of Fifth	Third div. of Fifth & Upper Remove	Lower Remove	Upper Shell	Middle & Lower Shells	Fourth	Totals
Sixth	—	4	2	6	3	1	2	18
First and Second divisions of Fifth	4	36	41	20	18	17	5	141
Third division of Fifth and Upper Remove	2	41	80	70	42	63	24	322
Lower Remove	6	20	70	110	100	103	87	496
Upper Shell	3	18	42	100	92	119	89	463
Middle & Lower Shells	1	17	63	103	119	174	110	587
Fourth	2	5	24	87	89	110	196	513
Totals	18	141	322	496	463	587	513	2540

$C_1 = \cdot 39, \qquad C_2 = \cdot 38.$

Table VIII B.

First Brother

Second Brother	Upper Shell & Higher	Middle Shell & Lower	Totals
Upper Shell & Higher	930	510	1440
Middle Shell & Lower	510	590	1100
Totals	1440	1100	2540

$r = \cdot 28.$

Table VIII C.

First Brother

Second Brother	Lower Remove & Above	Upper Shell & Below	Totals
Lower Remove & Above	512	465	977
Upper Shell & Below	465	1098	1563
Totals	977	1563	2540

$r = \cdot 36.$

Table IX A.

First Brother

Second Brother	Sixth	First and Second divisions of Fifth	Third div. of Fifth & Upper Remove	Lower Remove	Upper Shell	Middle & Lower Shells	Fourth	Totals
Sixth	54	57	25	27	6	6	2	177
First and Second divisions of Fifth	57	128	70	79	40	27	5	406
Third division of Fifth and Upper Remove	25	70	72	91	59	46	11	374
Lower Remove	27	79	91	94	51	58	8	408
Upper Shell	6	40	59	51	38	30	12	236
Middle & Lower Shells	6	27	46	58	30	54	18	239
Fourth	2	5	11	8	12	18	6	62
Totals	177	406	374	408	236	239	62	1902

$C_1 = \cdot 37, \qquad C_2 = \cdot 38.$

Table IX B.

First Brother

Second Brother	Upper Remove & Above	Lower Remove & Below	Totals
Upper Remove & Above	558	399	957
Lower Remove & Below	399	546	945
Totals	957	945	1902

$r = \cdot 25.$

Table IX C.

First Brother

Second Brother	Second division of Fifth & Above	Third division of Fifth & Below	Totals
Second division of Fifth & Above	296	287	583
Third division of Fifth & Below	287	1032	1319
Totals	583	1319	1902

$r = \cdot 46.$

Table X A.

First Brother

Second Brother	Sixth	First and Second divisions of Fifth	Third div. of Fifth & Upper Remove	Lower Remove	Upper Shell	Middle & Lower Shells	Fourth	Totals
Sixth	170	108	51	18	3	3	—	353
First and Second divisions of Fifth	108	138	106	54	12	6	1	425
Third division of Fifth and Upper Remove	51	106	60	35	18	7	—	277
Lower Remove	18	54	35	26	8	7	1	149
Upper Shell	3	12	18	8	4	4	1	50
Middle & Lower Shells	3	6	7	7	4	6	1	34
Fourth	—	1	—	1	1	1	—	4
Totals	353	425	277	149	50	34	4	1292

$C_1 = \cdot 39, \qquad C_2 = \cdot 38.$

Table X B.

First Brother

Second Brother	Second division of Fifth & Above	Third division of Fifth & Below	Totals
Second division of Fifth & Above	524	254	778
Third division of Fifth & Below	254	260	514
Totals	778	514	1292

$r = \cdot 28.$

Table X C.

First Brother

Second Brother	Upper Remove & Above	Lower Remove & Below	Totals
Upper Remove & Above	898	157	1055
Lower Remove & Below	157	80	237
Totals	1055	237	1292

$r = \cdot 35.$

Table XI A.

First Brother

Second Brother	I*	II	III	IV	V	VI	VII	Totals
I	—	2	2	2	—	—	—	6
II	2	6	25	13	11	6	5	68
III	2	25	102	79	55	52	25	340
IV	2	13	79	68	86	53	43	344
V	—	11	55	86	124	99	65	440
VI	—	6	52	53	99	170	99	479
VII	—	5	25	43	65	99	100	337
Totals	6	68	340	344	440	479	337	2014

* For explanation of these figures *vide* text.

$C_1 = \cdot 38, \qquad C_2 = \cdot 45.$

Table XI B.

First Brother

Second Brother	V and Above	VI and Below	Totals
V and Above	850	348	1198
VI and Below	348	468	816
Totals	1198	816	2014

$r = \cdot 44.$

Table XI C.

First Brother

Second Brother	IV and Above	V and Below	Totals
IV and Above	422	336	758
V and Below	336	920	1256
Totals	758	1256	2014

$r = \cdot 45.$

TABLE XII A.

Second Brother \ First Brother	I	II	III	IV	V	VI	VII	Totals
I	10	29	19	10	2	2	—	72
II	29	124	92	56	31	14	5	351
III	19	92	92	71	36	19	6	335
IV	10	56	71	84	47	21	5	294
V	2	31	36	47	60	33	14	223
VI	2	14	19	21	33	28	4	121
VII	—	5	6	5	14	4	4	38
Totals	72	351	335	294	223	121	38	1434

$C_1 = .39, \qquad C_2 = .45.$

TABLE XII B.

Second Brother \ First Brother	III and Above	IV and Below	Totals
III and Above	506	252	758
IV and Below	252	424	676
Totals	758	676	1434

$r = .45.$

TABLE XII C.

Second Brother \ First Brother	II and Above	III and Below	Totals
II and Above	192	231	423
III and Below	231	780	1011
Totals	423	1011	1434

$r = .37.$

Table XIII A.

First Brother

Second Brother	I	II	III	IV	V	VI	VII	Totals
I	66	72	19	13	4	—	1	175
II	72	126	54	22	10	4	—	288
III	19	54	62	24	8	2	1	170
IV	13	22	24	22	11	3	—	95
V	4	10	8	11	4	—	—	37
VI	—	4	2	3	—	—	—	9
VII	1	—	1	—	—	—	—	2
Totals	175	288	170	95	37	9	2	776

$C_1 = \cdot 38, \qquad C_2 = \cdot 45.$

Table XIII B.

First Brother

Second Brother	II and Above	III and Below	Totals
II and Above	336	127	463
III and Below	127	186	313
Totals	463	313	776

$r = \cdot 49.$

Table XIII C.

First Brother

Second Brother	III and Above	IV and Below	Totals
III and Above	544	89	633
IV and Below	89	54	143
Totals	633	143	776

$r = \cdot 42.$

Table XIV A.

First Brother

Second Brother	I	II	III	IV	V	VI	VII	Totals
I	—	9	2	1	2	—	—	14
II	9	72	64	56	38	22	5	266
III	2	64	76	60	67	36	6	311
IV	1	56	60	100	81	68	14	380
V	2	38	67	81	106	89	30	413
VI	—	22	36	68	89	102	47	364
VII	—	5	6	14	30	47	14	116
Totals	14	266	311	380	413	364	116	1864

$C_1 = \cdot 38, \qquad C_2 = \cdot 40.$

Table XIV B.

First Brother

Second Brother	III and Above	IV and Below	Totals
III and Above	298	293	591
IV and Below	293	980	1273
Totals	591	1273	1864

$r = \cdot 43.$

Table XIV C.

First Brother

Second Brother	IV and Above	V and Below	Totals
IV and Above	632	339	971
V and Below	339	554	893
Totals	971	893	1864

$r = \cdot 41.$

TABLE XV A.

First Brother

Second Brother	I	II	III	IV	V	VI	VII	Totals
I	26	39	9	3	2	3	—	82
II	39	216	113	79	49	17	—	513
III	9	113	74	80	45	23	4	348
IV	3	79	80	94	74	36	8	374
V	2	49	45	74	66	24	9	269
VI	3	17	23	36	24	30	5	138
VII	—	—	4	8	9	5	2	28
Totals	82	513	348	374	269	138	28	1752

$C_1 = \cdot 44, \qquad C_2 = \cdot 46.$

TABLE XV B.

First Brother

Second Brother	II and Above	III and Below	Totals
II and Above	320	275	595
III and Below	275	882	1157
Totals	595	1157	1752

$r = \cdot 47.$

TABLE XV C.

First Brother

Second Brother	III and Above	IV and Below	Totals
III and Above	638	305	943
IV and Below	305	504	809
Totals	943	809	1752

$r = \cdot 46.$

TABLE XVI A.

Second Brother \ First Brother	I	II	III	IV	V	VI	VII	Totals
I	94	93	17	12	5	—	—	221
II	93	238	90	48	16	3	—	488
III	17	90	60	44	17	5	—	233
IV	12	48	44	24	8	3	1	140
V	5	16	17	8	20	3	—	69
VI	—	3	5	3	3	—	—	14
VII	—	—	—	1	—	—	—	1
Totals	221	488	233	140	69	14	1	1166

$C_1 = \cdot 44, \qquad C_2 = \cdot 43.$

TABLE XVI B.

Second Brother \ First Brother	II and Above	III and Below	Totals
II and Above	518	191	709
III and Below	191	266	457
Totals	709	457	1166

$r = \cdot 48.$

TABLE XVI C.

Second Brother \ First Brother	III and Above	IV and Below	Totals
III and Above	792	150	942
IV and Below	150	74	224
Totals	942	224	1166

$r = \cdot 32.$

Measures of Resemblance between Brother and Brother found by different methods.

Table VII.

Oxford.

Date of Degrees taken by Sons	C_1 = Mean square Contingency Coefficient	C_2 = Mean Contingency Coefficient	r = Correlation Coefficient found by the 4-fold Correlation Method			Mean of r's
1860—1892	·32	·39	found from Table IV B. ·38	found from Table IV C. ·40	found from Table IV D. ·40	·393
1830—1860	·30	·36	found from Table V B. ·37	found from Table V C. ·39	found from Table V D. ·43	·397
1800—1830	·31	·29	found from Table VI B. ·42	found from Table VI C. ·43		·425

Table XVII.

Harrow and Charterhouse.

Material	Year or Age of Boy	Mean square Contingency Coefficient	Mean Contingency Coefficient	Correlation Coefficient	Correlation Coefficient	Mean Correlation Coefficient
Harrow, later	Year I	Table VIII A. ·39	Table VIII A. ·38	Table VIII B. ·28	Table VIII C. ·36	·320
	Year II	Table IX A. ·37	Table IX A. ·38	Table IX B. ·25	Table IX C. ·46	·355
	Year III	Table X A. ·39	Table X A. ·38	Table X B. ·28	Table X C. ·35	·315
Harrow, earlier	Year I	Table XI A. ·38	Table XI A. ·45	Table XI B. ·44	Table XI C. ·45	·445
	Year II	Table XII A. ·39	Table XII A. ·45	Table XII B. ·45	Table XII C. ·37	·410
	Year III	Table XIII A. ·38	Table XIII A. ·45	Table XIII B. ·49	Table XIII C. ·42	·455
Charterhouse	Age of Boy, 15	Table XIV A. ·38	Table XIV A. ·40	Table XIV B. ·43	Table XIV C. ·41	·420
	Age of Boy, 16	Table XV A. ·44	Table XV A. ·46	Table XV B. ·47	Table XV C. ·46	·465
	Age of Boy, 17	Table XVI A. ·44	Table XVI A. ·43	Table XVI B. ·48	Table XVI C. ·32	·400
General Means.....		·395	·420			·398

APPENDIX.

INFLUENCE OF ACADEMIC SELECTION ON CORRELATION COEFFICIENTS.

By KARL PEARSON, F.R.S.

In the course of the present memoir it has been assumed that the fathers and sons who go to Oxford are not an intellectually selected class. In other words the academic population is supposed to have as great intellectual variability as the community at large. This can hardly be the case; in the first place, there is a mild intellectual test in the matriculation examinations, which excludes at least some of the very intellectually defective. Secondly, there is already a class selection; there has been in the near or distant past ability in the stock sufficient to raise it to that pecuniary position in which going to the university becomes a tradition; thirdly and lastly, a considerable number of men go to Oxford because they have shown by position in their schools, or by obtaining school or college scholarships, that they are likely to do well at the university. There is small doubt therefore that the academic population belongs to a selected class and one with considerably less intellectual variation than is to be found in the community at large. This selection of intelligence leads at once to the reduction of the correlation coefficients between father and son, and brother and brother. It would be very difficult to obtain a precise numerical estimate of the amount by which the academic population is less intellectually variable than the general population. The reduction can hardly be less than 15 per cent.*, and some estimates might make it as high as 25 per cent., owing to the heaping up of the specially intelligent group by the prizes and rewards offered to very capable boys in a considerable number of social classes†. It seems worth while investigating the results which arise from supposing 15 and 25 p.c. of selection.

Let ρ_{13} be the observed correlation between fathers and sons both at the university; r_{13} the true correlation of intelligence between father and son in the race; μ the ratio of variability in the academic population to that in the community at large in the matter of intelligence. Then‡

$$r_{13} = \rho_{13} / \sqrt{\mu^2 + \rho_{13}^2 (1 - \mu^2)}.$$

Now $\rho_{13} = \cdot 33 = \frac{1}{3}$ say; hence in the present case

$$r_{13} = 1 / \sqrt{1 + 8\mu^2}.$$

* This would be about the sort of reduction which would arise if we cut off the bulk of the slow dull and very dull members of the general population.

† Certain intellectually selected classes send their sons by tradition; other classes send only the pick of their intelligence.

‡ *Phil. Trans.*, Vol. 200 A, p. 39.

If $\mu = \cdot 85$, i.e. 15 p.c. reduction in variability of intelligence, $r_{13} = \cdot 385$. If $\mu = \cdot 25$, i.e. 25 p.c. reduction in variability of intelligence, we have $r_{13} = \cdot 43$.

But these values do not represent the whole reduction, because a similar selection has taken place with regard to sons. They represent the correlation between fathers at or not at the university and sons at the university. Accordingly repeating the calculations with $\rho_{13} = \cdot 385$ and $\cdot 43$ respectively, we find for r_{13}' the correlation of father and son in general:

$$r_{13}' = \cdot 44 \text{ and } \cdot 54 \text{ respectively.}$$

No special stress is laid on these particular numerical results, but they suffice to show that, if the variability in intelligence in the academic population be 15 to 25 per cent. less than in the general population, the actual correlation in intelligence between father and son as a racial heredity constant must lie between $\cdot 44$ and $\cdot 54$, i.e. much in excess of the value $\cdot 33$ deduced from the selected population.

Assuming the observed correlation of brothers of the academic class to be $\cdot 4$, and using the same formulae, i.e.

$$r_{34} = \rho_{34} / \sqrt{\mu^2 + \rho_{34}^2 (1 - \mu^2)},$$

where ρ_{34} is the observed and r_{34} the actual fraternal correlation in intelligence in the general community, we find, by the selection of the first brother, $r_{34} = \cdot 46$, if the variability be reduced by 15 p.c., and $r_{34} = \cdot 50$, if it be reduced 25 p.c. These are the values of fraternal correlation for one brother at the university and the other at or not at the university. Repeating the process with $\rho_{34}' = \cdot 46$ and $\cdot 50$, we find that, owing to the selection of both brothers, $r_{34}' = \cdot 52$ with 15 p.c. reduction and $= \cdot 61$ with 25 p.c. reduction.

Accordingly it seems reasonable to suppose that if the intelligence of the academic class has a less wide range of variability than that of the general population, the coefficient of parental heredity for intelligence lies between $\cdot 4$ and $\cdot 5$, and that of fraternal resemblance between $\cdot 5$ and $\cdot 6$.

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